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Laser Beam Control in Strong Turbulence (Preprint)

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Journal Article

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14. ABSTRACT
The overall purpose of this task is to investigate control and diagnostic techniques that apply to laser propagation systems. The current emphasis is in two major areas: first to investigate full wave conjugation methods for optimal uplink efficiency from a laser source to a relay mirror, second, to investigate automatic diagnostic techniques that apply to complex systems Air Force systems.

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Laser Beam Control in Strong Turbulence

Laboratory Task LRIR: 93PL001

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Objectives

The overall purpose of this task is to investigate control and diagnostic techniques that apply to laser propagation systems. The current emphasis is in two major areas: first to investigate full wave conjugation methods for optimal uplink efficiency from a laser source to a relay mirror; second, to investigate automatic diagnostic techniques that apply to complex systems Air Force systems.

Status of Effort

The investigation of optimal uplink methods for relay mirror uplink efficiency has moved from the analysis and simulation stages of the past few years into a hardware demonstration phase. Recent publications (see last years report) document the methodology that will be implemented in this multi-year hardware phase. This year a simple energy rearrangement experiment is being conducted to demonstrate the first part of the full wave conjugation system that will be required on two ends of a relay mirror path for optimal uplink efficiency. The automatic diagnostic portion of the effort seeks to explore two basic approaches in automatic fault detection. This year the feasibility of model-based methods utilizing an advanced pattern recognition library was investigated

with the view toward later application in Air Force systems. The second approach, output signature monitoring, primarily using power spectral density techniques al la Tryphon Georgiou, is being studied for possible application to real data next year.

Accomplishments

The first subtask, optimal relay uplinks, is performing an energy redistribution experiment as a first step in creating an experiment to demonstrate iterative full wave conjugation methods to relay uplinks. This years experiment will send a laser beam through an aberrating media and then propagate it through a distance sufficient to cause scintillation. At this point both the phase and the scintillation on the beam will be sensed. The sensed data will be used in an algorithm to drive a deformable mirror to redistribute the laser energy to smoothly fill an aperture. At this new aperture the phase and amplitude of the beam will be sensed to determine how well the energy was redistributed and what the redistribution did to the phase. This is the first step in implementing the iterative full wave conjugation schemes documented in last years report. To date we have identified equipment, a deformable mirror and wavefront sensor, a laboratory for the demonstration, and have completed a preliminary optical design. A simulation of the optical setup is being coded.

For the second subtask, automatic diagnosis, progress was made on input-output analysis based on a system model. Three individual 'experts' were developed to compare input and output data and to determine if the plant changed relative to the model. The three 'experts' were based on Associative Neural Networks, Kohonen Self Organizing Maps, and the Radial Based Clustering algorithms respectively. The set of individual experts were then managed by a Gated Expert algorithm, which assigned the experts, based on their best performance regions. A Matlab Simulink model of a Chiller system was used to test the overall algorithm. We also have made significant progress in building a simulation of an Air Force system in conjunction with the University of New Mexico. The algorithm will be tested against this model in the near future. Additionally, several of our field test site subsystems are being modeled by a team of graduate students at the University of New Mexico under the supervision of Professor Jamshidi. This is in preparation for testing the algorithms at that site against real field data. Finally, data from an actual aircraft mission has been secured from the Boeing Corporation to facilitate application of the algorithms to real aircraft data. We have also begun a study of the theoretical results of Tryphon Georgiou, et al. which use Kullback-Leiber distance measures to apply to both the aircraft and field test data next year.

Personnel Supported

Dr Don Washburn, AFOSR task manager

Dr Troy Rhoadarmer, Optimal Uplink Subtask Manager

Charles Finley, Optical design and simulation for Optimal Uplink Task

Dr Dan Herrick, Diagnostic Subtask Manager

Professor Mohammed Jamshidi (IPA), Principal Investigator Diagnostic Subtask

Victor Stone, Researcher on Diagnostic Task

Interactions

Professor Tryphon Georgiou – University of Minnesota

Professor Steve Gibson – UCLA

Professor Allen Tannenbaum – Georgia Tech

Transitions

The adaptive reconstruction work of Steve Gibson is being transitioned to 6.2 via an SBIR and by direct help from Steve Gibson to AFRL/DES. It is expected to be tested in an AFRL/DES laboratory in the coming year. In addition two SBIRs are building processors to implement the algorithm in real time.

A tracking algorithm based on the medical imagery work of Allen Tannenbaum is being investigated in simulation and will be implemented in the coming year at an Air Force test site.

The in-house work in optimal relay mirror uplink power beaming has been validated in simulation and will be implemented both in the laboratory and at an Air Force test site as funding permits.

Publications

H. Berenji, D. Herrick and M. Jamshidi," Data Mining Based Algorithms for Prognostic Studies of the ABL System," Paper presented at the *6th Annual Directed Energy Symposium*, October 22-24, 2003, Albuquerque, NM

M. Jamshidi, D. Herrick, D. Washburn and H. Berenji, "Design, Control and Prognostic of a Laser Pointing System," *Proc. Laser Systems Technology Conference*, 12-16 April 2004, Orlando, Florida

Y. Wang, F. Benito, G. A. Vera, and M. Jamshidi "Control Design for Diagnostic and Prognostic of Hardware Systems," *Proc. FUZZ-IEEE Conference*, Budapest, Hungary, July 25-28, 2004.

V. Stone, K. Meadows, and M. Jamshidi, "An Investigation of Health Monitoring, Prognostic, and Diagnostic Techniques Using Pattern Recognition and Data Mining," to be presented at AMOS Conference, September 13-17, 2004, Maui, HI.

H. Berenji, Y. Wang, R. Langari and M. Jamshidi, " Using Gated Experts in Fault Diagnosis and Prognosis," *Proc. FUZZ-IEEE Conference*, Budapest, Hungary, July 25-28, 2004